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Special Report 1

Stanford Research Institute Project 5414

CORRECTION TO RANGE OF HEAD ECHO FOR BK

by

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CORRECTION TO RANGE OF HEAD ECHO FOR BK19

SRI has been involved in the design and development of the DAZZLE radar and analysis of the data derived therefrom. The radar was designed specifically for study of re-entry phenomena at 55 Mc and 153 Mc. It is located at Central Boro on the missile testing range near Woomera, South Australia. Previous results on the first two firings of the Black Knight in the DAZZLE series, BK19 and BK20, have been reported in Semiannual Technical Report V and Special Report 1 for Contract DA-04-200-ORD-1268.

The data analysis has been hampered by the jitter of the head echo within the range gate from one pulse code group to another. Although it was realized in the design of the radar that the position of the head echo in the range gate would need to be determined from one pulse code group to the next, it had been assumed that the head echo would be much stronger than was actually observed. The smaller signal-to-noise ratio measured is due to the degraded antenna performance (two-way gain down 12 db) at 153 Mc caused by mutual coupling in the antenna feed system. Determination of the head location, therefore, requires further effort than had been anticipated.

In order to obtain the required range resolution for the Project DAZZLE radar, the data are recorded on high-speed film with a fast time base. Each successive pulse return is recorded separated in A-scope format (see Fig. 1) with a 25-μsec time base. During re-entry the target range rate is on the order of 5 km/sec, thus an automatic range tracking system is required. The high range-resolution data make use of transmitted pulses 0.25 μsec long. This pulse return from the re-entry head, as received in a 10-Mc IF bandwidth, does not provide sufficient signal-to-noise ratio to provide reliable range tracking. The range tracking system therefore operates on a 10-μsec pulse return, as received in a 100-kc IF bandwidth. The range tracking stability thus obtained is not as good as desired but is the best that can be achieved with the system sensitivity available. In addition, the wake returns behind the head adversely affect the apparent position of the head as the wake behind the head periodically builds up and collapses.

The range tracking unit controls the radar synchronizer which, in turn, determines the timing of the transmitter pulses and corresponding delayed triggers preceding each of the returned echoes. A pulse code is normally transmitted and consists of a tracking pulse 10 μsec in length followed 6.1 msec later by a train of pulses termed pulse train A, the first of which is followed 6.1 msec later by another pulse train termed pulse train B. Following the first pulse of train B by 6.1 msec, the tracking pulse and successive pulse trains are again repeated. The pulse width and spacing of pulse trains A and B

are separately controllable, as are the number of pulses within a train up to a maximum of 10. A delayed trigger is generated following each pulse of the pulse code, the amount of the delay being determined by the range tracking system. For a given pulse code consisting of a tracking pulse and two pulse trains, the delay between the transmitted pulse and the delayed trigger is constant to within ±20 nsec. The delay is corrected once every pulse train, so that the relative position of the head return with respect to the delayed trigger can change from one pulse train to the next but not within a given train. Correlation studies within a pulse train are therefore readily achievable but are more difficult from one pulse train to the next. Thus, when observing the head echo there is an apparent jitter in range.

It is possible to measure the relative range from the delayed trigger to the echo return from the second stage, since the second stage produces a strong echo throughout re-entry. This relative delay, as determined by a measurement to the leading edge of the second-stage echo, is plotted in Fig. 2. The relative range between the second stage and the head is known to be a smooth monotonically varying function. In order to obtain a smoothed curve corresponding to the actual position of the second stage, a least-mean-square fit to a third-order polynomial has been made to the points in Fig. 2. The difference between the points and the best-fit trajectory then corresponds to the relative position of the head with respect to the delayed trigger. These values are tabulated in Table I. A negative delay requires that the head echo be shifted closer to the delayed trigger. By shifting each A-scope trace an amount given in Table I, all successive traces should line up so that the position of the head return for successive pulse code groups can be determined.

Since the position of the delayed trigger can shift with respect to the head echo from one pulse train to the next, this series of measurements needs to be done for each train separately. The values given in Table I are only for pulse train B, the series of ten pulses spaced 600 μsec apart. The measurements presented used the last pulse in each train as indicated by the arrow in Fig. 1. The pulse train corresponding to pulse No. 1 in Table I is defined in Fig. 1. The time shown (time after lift-off and universal time) corresponds to the TIM 100 time marks on the edge of the film.

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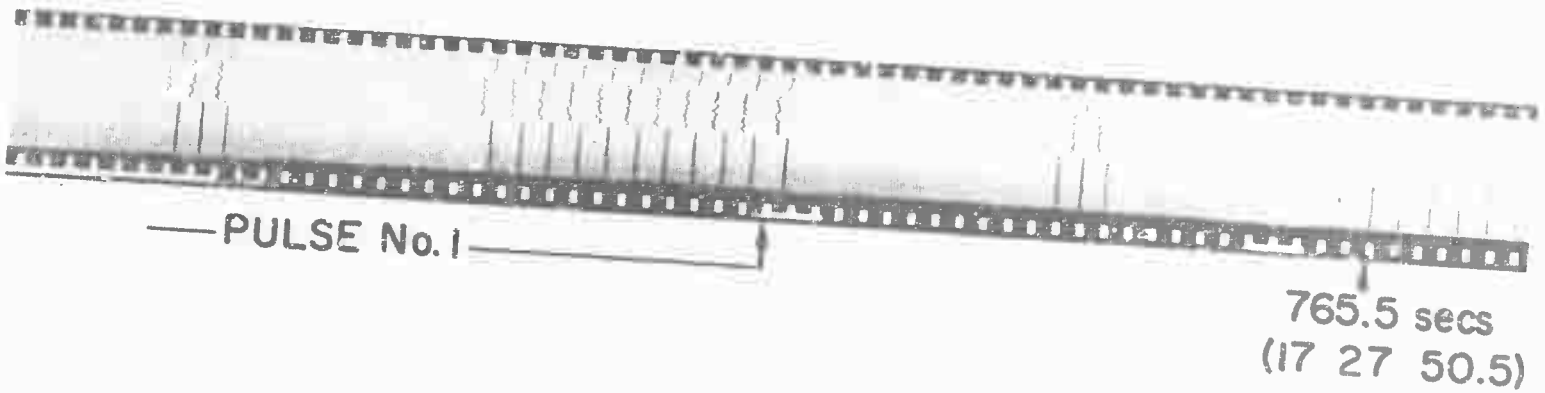
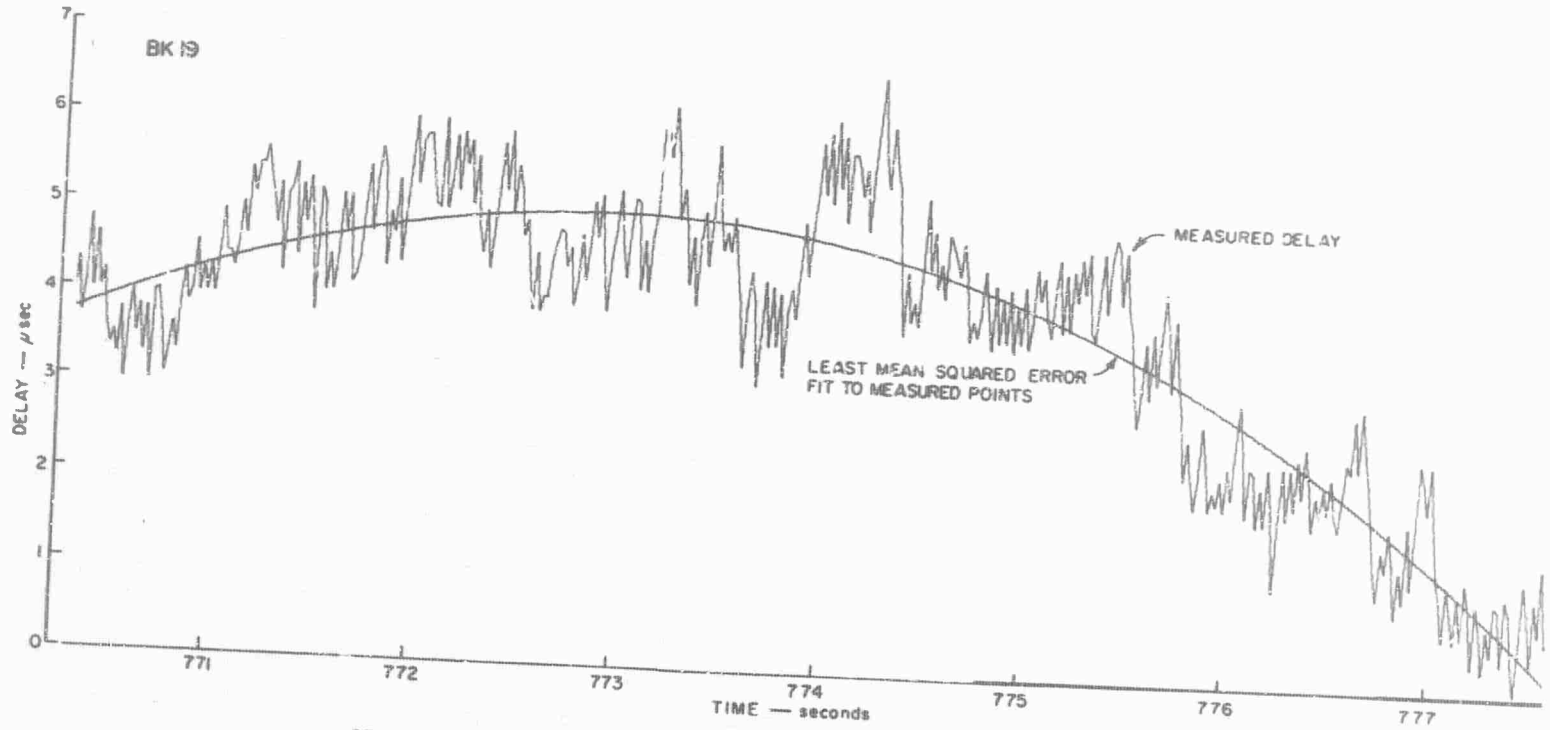


COMMENCEMENT OF RANGE CORRECTION MEASUREMENT FOR BK 19

FIG. 1



DELAY OF SECOND STAGE RETURN RELATIVE TO TRIGGER PULSE AS A FUNCTION OF TIME

FIG. 2

Pulse Code Number	Delay
1	-.10 μsec
2	-.55 μsec
3	.06 μsec
4	-.25 μsec
5	-.98 μsec
6	-.16 μsec
7	-.76 μsec
8	-.14 μsec
9	-.31 μsec
10	.27 μsec
11	.53 μsec
12	.40 μsec
13	.67 μsec
14	.18 μsec
15	.98 μsec
16	.36 μsec
17	.00 μsec
18	.50 μsec
19	.22 μsec
20	.74 μsec
21	.27 μsec
22	1.08 μsec
23	.11 μsec
24	.10 μsec
25	.49 μsec
26	1.06 μsec
27	.79 μsec
28	.51 μsec
29	.84 μsec
30	.31 μsec
31	-.02 μsec
32	.33 μsec
33	.23 μsec
34	-.30 μsec
35	.28 μsec
36	.00 μsec
37	.29 μsec
38	.01 μsec
39	.33 μsec
40	-.09 μsec
41	-.57 μsec
42	-.07 μsec
43	-.06 μsec
44	.10 μsec
45	-.14 μsec
46	-.58 μsec

Pulse Code Number	Delay
47	-.21 μsec
48	-.95 μsec
49	-.66 μsec
50	-.98 μsec
51	-.95 μsec
52	-1.14 μsec
53	-.81 μsec
54	-.58 μsec
55	-.25 μsec
56	-.70 μsec
57	.29 μsec
58	-.56 μsec
59	-.64 μsec
60	-.88 μsec
61	.14 μsec
62	-.63 μsec
63	-.19 μsec
64	-.69 μsec
65	-.13 μsec
66	.80 μsec
67	-.54 μsec
68	-.36 μsec
69	.60 μsec
70	.21 μsec
71	.61 μsec
72	.24 μsec
73	-.43 μsec
74	-.01 μsec
75	-.41 μsec
76	.56 μsec
77	.48 μsec
78	.30 μsec
79	-.29 μsec
80	-.69 μsec
81	.03 μsec
82	-.55 μsec
83	-.88 μsec
84	-.63 μsec
85	.14 μsec
86	-.14 μsec
87	.09 μsec
88	-.49 μsec
89	.42 μsec
90	-.16 μsec
91	-.61 μsec
92	-1.18 μsec

Pulse Code Number	Delay
93	-.41 μsec
94	-.90 μsec
95	-.97 μsec
96	-.96 μsec
97	-.52 μsec
98	-.16 μsec
99	-.11 μsec
100	-1.12 μsec
101	-.09 μsec
102	-.40 μsec
103	-.91 μsec
104	-.29 μsec
105	-.94 μsec
106	-.57 μsec
107	-.83 μsec
108	-.12 μsec
109	-.65 μsec
110	.14 μsec
111	.41 μsec
112	-.04 μsec
113	.60 μsec
114	.16 μsec
115	-.29 μsec
116	-.79 μsec
117	-.25 μsec
118	-.92 μsec
119	-.00 μsec
120	-.52 μsec
121	-.27 μsec
122	.25 μsec
123	.08 μsec
124	.67 μsec
125	1.07 μsec
126	.44 μsec
127	1.08 μsec
128	.93 μsec
129	.94 μsec
130	.52 μsec
131	.33 μsec
132	.18 μsec
133	.24 μsec
134	.60 μsec
135	.39 μsec
136	1.04 μsec
137	.77 μsec
138	.24 μsec

Pulse Code Number	Delay	Pulse Code Number	Delay	Pulse Code Number	Delay
139	.74 µsec	185	.78 µsec	231	-.81 µsec
140	.37 µsec	186	1.73 µsec	232	-.04 µsec
141	-.12 µsec	187	1.15 µsec	233	-.47 µsec
142	.27 µsec	188	.55 µsec	234	.13 µsec
143	-.20 µsec	189	1.26 µsec	235	-.14 µsec
144	.57 µsec	190	.59 µsec	233	.21 µsec
145	1.08 µsec	191	1.24 µsec	237	-.48 µsec
146	.49 µsec	192	.66 µsec	238	-.38 µsec
147	.18 µsec	193	1.56 µsec	239	-.25 µsec
148	-.26 µsec	194	.82 µsec	240	-.08 µsec
149	.35 µsec	195	.58 µsec	241	-.45 µsec
150	.70 µsec	196	.89 µsec	242	-.12 µsec
151	.13 µsec	197	.34 µsec	243	.58 µsec
152	-.17 µsec	198	-.17 µsec	244	.35 µsec
153	-.13 µsec	199	.40 µsec	245	.50 µse
154	.82 µsec	200	-.12 µsec	246	.26 µse
155	.27 µsec	201	-.53 µsec	247	-.25 µse
156	.84 µsec	202	-1.10 µsec	248	.16 µsec
157	.21 µsec	203	-.53 µsec	249	.59 µsec
158	-.03 µsec	204	-1.23 µsec	250	-.13 µsec
159	-1.10 µsec	205	-.45 µsec	251	.48 µsec
160	-1.02 µsec	206	-1.39 µsec	252	-.02 µsec
161	-.66 µsec	207	-.64 µsec	253	.45 µsec
162	-1.23 µsec	208	-1.23 µsec	254	-.15 µsec
163	-.73 µsec	209	-.28 µsec	255	.51 µsec
164	.01 µsec	210	-1.05 µsec	256	.01 µsec
165	-.33 µsec	211	-1.06 µsec	257	.38 µsec
166	.05 µsec	212	-.92 µsec	258	-.25 µsec
167	.71 µsec	213	-.62 µsec	259	.40 µsec
168	.18 µsec	214	-.93 µsec	260	.09 µsec
169	.94 µsec	215	-.25 µsec	261	-.50 µsec
170	.17 µsec	216	-.97 µsec	262	-.18 µsec
171	-.10 µsec	217	-1.48 µsec	263	-.45 µsec
172	.49 µsec	218	-2.00 µsec	264	-.01 µsec
173	-.05 µsec	219	-1.11 µsec	265	.16 µsec
174	-.86 µsec	220	-.79 µsec	266	-.33 µsec
175	-.12 µsec	221	-1.48 µsec	267	-.71 µsec
176	.29 µsec	222	-1.08 µsec	268	.06 µsec
177	.08 µsec	223	-.84 µsec	269	-.59 µsec
178	.29 µsec	224	-.02 µsec	270	.00 µsec
179	-.08 µsec	225	.77 µsec	271	-.66 µsec
180	.44 µsec	226	.07 µsec	272	-.35 µsec
181	.82 µsec	227	.59 µsec	273	-.84 µsec
182	1.54 µsec	228	.37 µsec	274	-.48 µsec
183	.85 µsec	229	.61 µsec	275	-.95 µsec
184	.47 µsec	230	-.01 µsec	276	-.09 µsec

Pulse Code Number	Delay	Pulse Code Number	Delay	Pulse Code Number	Delay
277	-.03 µsec	324	.89 µsec	371	-.04 µsec
278	-.51 µsec	325	.22 µsec	372	.21 µsec
279	-1.02 µsec	326	.68 µsec	373	.59 µsec
280	-.39 µsec	327	1.52 µsec	374	-.02 µsec
281	-.39 µsec	328	.68 µsec	375	.23 µsec
282	-1.24 µsec	329	.10 µsec	376	.51 µsec
283	-1.14 µsec	330	.65 µsec	377	.01 µsec
284	-.56 µsec	331	.06 µsec	378	.40 µsec
285	-1.16 µsec	332	.48 µsec	379	-.23 µsec
286	-.55 µsec	333	-.03 µsec	380	.00 µsec
287	-.32 µsec	334	.29 µsec	381	.61 µsec
288	.27 µsec	335	-.27 µsec	382	-.10 µsec
289	.67 µsec	336	.07 µsec	383	.10 µsec
290	.27 µsec	337	.56 µsec	384	.57 µsec
291	-.29 µsec	338	.17 µsec	385	.04 µsec
292	.29 µsec	339	.38 µsec	386	.29 µsec
293	-.45 µsec	340	.02 µsec	387	-.29 µsec
294	.09 µsec	341	.28 µsec	388	-.27 µsec
295	-.41 µsec	342	-.15 µsec	389	.27 µsec
296	-.95 µsec	343	.21 µsec	390	-.47 µsec
297	-.56 µsec	344	.36 µsec	391	-.36 µsec
298	.07 µsec	345	-.02 µsec	392	.16 µsec
299	-.73 µsec	346	-.44 µsec	393	.44 µsec
300	-.14 µsec	347	-.37 µsec	394	-.19 µsec
301	.25 µsec	348	-.99 µsec	395	-.82 µsec
302	.94 µsec	349	-.45 µsec	396	-.55 µsec
303	.50 µsec	350	-1.14 µsec	397	.00 µsec
304	.80 µsec	351	-.70 µsec	398	-.75 µsec
305	1.20 µsec	352	-.40 µsec	399	-.43 µsec
306	.84 µsec	353	.02 µsec	400	-1.20 µsec
307	.24 µsec	354	.48 µsec		
308	.59 µsec	355	.76 µsec		
309	1.11 µsec	356	.20 µsec		
310	.88 µsec	357	.39 µsec		
311	1.00 µsec	358	-.07 µsec		
312	.70 µsec	359	.33 µsec		
313	1.02 µsec	360	.79 µsec		
314	.52 µsec	361	.26 µsec		
315	.83 µsec	362	.57 µsec		
316	.25 µsec	363	-.29 µsec		
317	-.26 µsec	364	.34 µsec		
318	.20 µsec	365	-.34 µsec		
319	.93 µsec	366	-1.08 µsec		
320	.36 µsec	367	-.89 µsec		
321	.40 µsec	368	-.61 µsec		
322	.95 µsec	369	-1.16 µsec		
323	.50 µsec	370	-.51 µsec		